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Measurement of Flow Velocity Using Video Image of Spherical Float

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Abstract

In this study flow velocity measurement using video images of a float was designed to measure flood discharge during heavy rainfall. A spherical float was used to obtain video image being not distorted according to oblique angle. The drifting distance of the spherical float was calculated by the inscribed and circumscribed vertical lengths of spherical float image from the center line based on geometric image interpretation. The flow velocities computed from Spherical Float Image Velocimetry (SFIV) coincided approximately with the real velocities in the open channel. The velocity coefficient value, the mean velocity by flowmeter to flow velocity of SFIV ratio, was 0.925 with standard deviation of 0.030. The results presented that SFIV may be utilized to determine the mean velocity and discharge in rivers.

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Keywords: Spherical float; Flow velocity; Video image; Geometric image interpretation

1. Introduction

During high flow event a current meter being in contact with the flow is not available but acoustic Doppler current profiler (ADCP) and large-scale particle image velocimetry (LSPIV) are used to measure fast flow velocity and flood discharge. The traditional and conventional float which is oldest method introduced first by Leonardo da

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Vinici [1] has several disadvantages such as the lead time of prepare, a number of persons, and the danger of the actual measurement, and insufficient accuracy [2]. Over past decades ADCP has collected the hydrologic data [3] but this method also has certain disadvantages, namely the high cost, the difficulty of taking continuous measurements, and the risk of gauging instruments and operators [4]. To overcome those problems LSPIV are used recently to estimate the surface velocity of a river with video [2, 5, 6]. However installation of a remotely-controlled camera system to record surface flow demands the expensive cost and LSPIV have showed inaccurate velocities by the low resolution of source image when the density and size of particles on the water surface is limited [6].

We develop spherical float image velocimetry (SFIV) combining the float and LSPIV. The depth-averaged velocity is estimated from spherical float images produced as floating tracer of LSPIV becomes the spherical float. The first part of this paper shows the processes to interpret geometrically the spherical float images. The second part presents the results of flow velocity calculated from spherical float images in an experimental open channel and evaluates a utility value of SFIV to measure velocity and discharge in the rivers.

2. Interpretation of spherical float image

A sphere is a round geometrical object in three-dimensional space that is the surface of a completely round ball. The shape of the sphere is not distorted according to oblique direction. The image size of sphere laid down in vertical line depends generally on the distance from the viewpoint. The spherical float images recoded in a video camera are interpreted based on geometrical principle (Fig. 1). An angle α_1 between a center line and a tangent line of the spherical float from the lens center of a camera is calculated by a focus length of the camera and the inscribed and circumscribed vertical lengths of the spherical float image from the center line. Therefore the length x_1 from the lens center of a camera to center of spherical float is obtained by sine α_1 and the radius of spherical float $d_0/2$. The distance $\overline{L_0L_1}$ from a viewpoint to first point L_1 after drafting first time T_1 is calculated as in Eq. (1)

$$\overline{L_0L_1} = \sqrt{{x_1}^2 - h^2} \tag{1}$$

The distance $\overline{L_0L_2}$ from a viewpoint to second point L_2 in drifting second time T_2 can be obtained by the same method as $\overline{L_0L_1}$.

Therefore flow velocity in the river is determined by Eq. (2).

$$V = \frac{\Delta L}{\Delta T} = \frac{\overline{L_0L_2} - \overline{L_0L_1}}{T_2 - T_1} \tag{2}$$

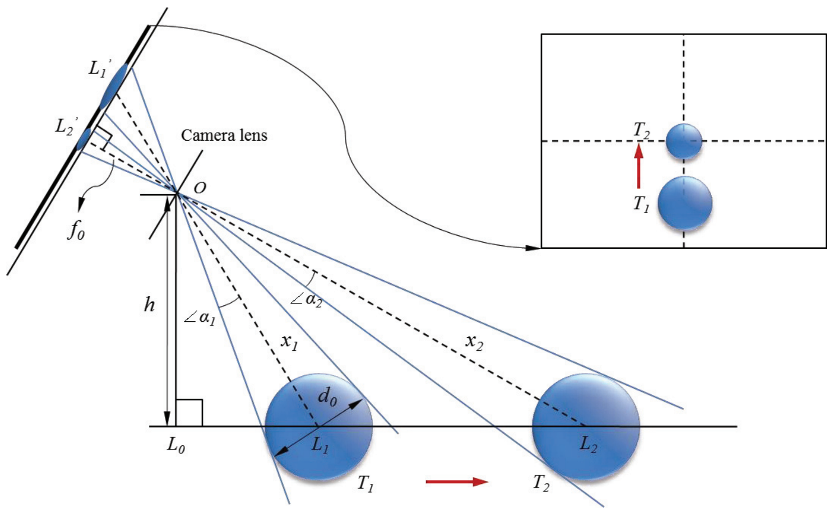

Fig. 1. Interpretation of geometric image of spherical floats to measure flow velocity

3. Evaluation of SFIV

3.1. Data collection and image capture

The tests in an open channel were performed to identify accuracy of the flow velocities calculated from the spherical float images. The width and length of the open channel are 0.6m and 9.0m respectively. The discharge in the channel was obtained through an ultrasonic flowmeter (TDS-100 of Zhuhai Able Autocontrol Equipment). The water stage was measured by an ultrasonic water-level gauge (F4Y=2D-1D0-330E of PIL Sensoren).

The sphere of spherical float was made of Styrofoam material and the submerged stick was a paper pipe filled with sand. The sticks of float to represent depth-averaged velocity prepared lengths of 0.1m and 0.2m being about 50% of flow depth.

The superhigh-speed cameras to take image of the drifting floats are installed in the cross and longitudinal directions of the experimental channel. Real velocity of spherical float passing a fixed three section points is measured by the number of frame of images recoded in longitudinal direction. The spherical float images captured in cross direction of the channel are utilized to evaluate the drifting distance with variation of spherical float size (Fig. 2). The inscribed and circumscribed vertical lengths of the spherical float from the center line of images of the floats drifting in cross section (a), (b), and (c) of the open channel are used to calculate an angle between center line and tangent line of spherical float from lens center of camera. We conducted three-repeat test with two kinds of stick at two cross sections to obtain total 12 data of the flow velocity for spherical float.

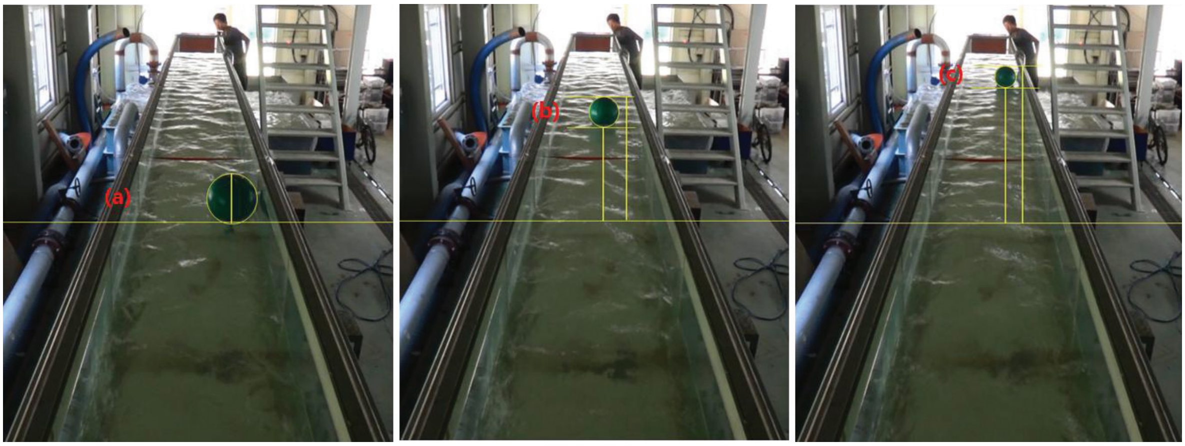

Fig. 2. Measurement of flow velocity from the size variation of the spherical float passing cross sections of (a), (b), and (c) in the open channel

3.2. Evaluation of flow velocity

Flow velocity computed from the video images of the spherical float with 0.1m stick was 0.255±0.016m/s and they for 0.2m stick showed the flow velocity of 0.636±0.030m/s. Flow velocities by SFIV coincided approximately with real flow velocities of the spherical float in an open channel (p= 0.000) as in Fig. 3.

Determination of area-average velocity is important to design and assess channels or rivers. Table 1 shows mean values for discharge measured by flowmeter and flow depth measured by water-level gauge. The mean velocities calculated from information of discharge and flow depth were compared to real velocities of the spherical float. The correlation coefficient of velocity, the ratio of the area-average velocity to depth-averaged velocity of the spherical float was 0.925 with standard deviation of 0.030 (Table 1).

In view of cost, effectiveness, and safety SFIV have more advantages rather than traditional float method. Additionally SFIV can measure depth-averaged velocity whereas LSPIV and ADCP measure only the surface velocity. The surface velocity from LSPIV and ADCP has to be converted into depth-average velocity. A constant velocity coefficient defined as ratio of the depth-average velocity to surface velocity is adopted commonly 0.85 for river flow studies [7-10]. However relationships between surface velocity and mean velocity presented by Cenç et al. (2015) and Ardiclioglu et al. (2013) [11, 12] in small river were greatly smaller than the literature values. It is that one of the key parameters for discharge calculation is the ratio of depth-average velocity to surface velocity. Therefore the SFIV measuring depth-average velocity is a useful method to assess the mean velocity and discharge in rivers.

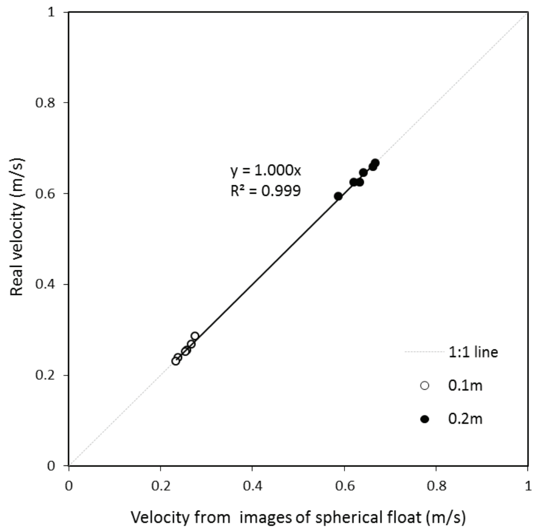

Fig. 3 Relationship between the real velocities and velocities calcuated from images of the spherical float

Table 1. Comparison of the area-average velocities and the spherical float velocities

Case no.	Section	Discharge Q(m^3/s)	Flow depth Y(m)	Mean velocity V_m(m/s)	Velocity of spherical float V_{SF}(m/s)	Correlation coefficient
1	a-b	141.7	36.6	0.583	0.650	0.896
2	b-c	142.0	37.3	0.568	0.621	0.915
3	a-b	32.7	22.8	0.244	0.264	0.922
4	b-c	33.4	23.5	0.238	0.246	0.966

4. Conclusion

The flow test in an experimental open channel was performed to identify the accuracy of flow velocity calculated from a spherical float image. Flow velocity from the video images of the spherical float with stick of 0.1m and 0.2m were respectively 0.255±0.016m/s and 0.636±0.030m/s. The flow velocity of SFIV coincided with the real velocity of a spherical float proves that the SFIV is the good velocity measurement method. The area-averaged velocity compared to real velocity of a spherical float showed the correlation coefficient of 0.925 with standard deviation of 0.030. The reason for the strong correlation is that SFIV can measure depth-averaged velocity whereas LSPIV and ADCP measure only the surface velocity. Therefore SFIV having advantages of efficiency, economical cost, and safety may be the fine method to determine the mean velocity and discharge in rivers. Even if the SFIV have the accuracy, further study for flood discharge measurement in the rivers is required to improve availability of SFIV.

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References

[1] J.P. Richter, The literary works of Leonardo da Vinci, London. (1939).
[2] R. Tsudaki, I. Fujita, S. Tsutsumi, Measurement of the flood discharge of a small-sized river using an existing digital video recording system, Journal of Hydro-environment Research. 5 (2011) 313-321.
[3] M. Muste, K. Yu, T. Pratt, D Abraham, Practical aspects of ADCP data use for quantification of mean river flow characteristics; Part II: fixed-vessel measurements. Flow Measurement and Instrumentation. 15 (2004) 17-28.
[4] J.D. Osorio-Cano, A.F. Osorio, R. Medina, A method for extracting surface flow velocities and discharge volumes from video images in laboratory, Flow Measurement and Instrumentation. (2013) 188-196.
[5] M. Jodeau, A. Hauet, A. Paquier, J. Le Coz, G. Dramais, Application and evaluation of LS-PIV technique for the monitoring of river surface velocities in high flow conditions, Flow Measurement and Instrumentation. 19 (2008) 117-127.
[6] D.W. Dobson, K.T. Holland, J. Calantoni, Fast, large-scale, particle image velocimetry-based estimations of river surface velocity, Computers & Geosciences. 70 (2014) 35-43.
[7] J.D. Creutin, M. Muste, A.A. Bradley, S.C. Kim, A. Kruger, River gauging using PIV techniques: a proof of concept experiment on the Iowa river, Journal of Hydrology. 277 (2003) 182–194.
[8] A. Hauet, A. Kruger, W.F. Krajewski, A.Bradley, M. Muste, J.D. Creutin, Experimental system for real-time discharge estimation using an image-based method, Journal of Hydrological Engineering. 13 (2008) 105–110.
[9] Y. Kim, M. Muste, A. Hauet, W.F. Krajewski, A. Kruger, A. Bradley, Stream discharge using mobile large-scale particle image velocimetry: a proof of concept, Water Resources Research. 44 (2008) W09502.
[10] M. Muste, I. Fujita, A. Hauet, Large-scale particle image velocimetry for measurements in riverine environments, Water Resour Res. 44 (2008) 1-14, doi:10.1029/2008WR006950.
[11] O. Cenç, M. Ardıçlıoğlu N. Ağıralioğlu, Calculation of mean velocity and discharge using water surface velocity in small streams, Flow Measurement and Instrumentation. 41 (2015) 115-120.
[12] M. Ardiclioglu, S. Ozdin, E. Gemici, Comparison of different methods for specifying flow rates of shallow streams, Bartın Univ. Eng.Technol. Sci. J. 1 (2013) 45–64.